TRANSACTIONS

OF THE

ILLUMINATING ENGINEERING SOCIETY

FOUNDED IN LONDON 1909 : INCORPORATED 1930

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VOLUME II—No. 3
MARCH, 1937

32 VICTORIA STREET
LONDON SWI

NOTES ON RECENT MEETINGS AND EVENTS

General Meeting in London.

A meeting of the Society was held in the Lecture Theatre of the E.L.M.A. Lighting Service Bureau (2, Savoy Hill, London, W.C.2), on Tuesday, February 23. The chair was taken by the President at 7 p.m.

The minutes of the last meeting having been taken as read, the names of applicants for membership were presented in the usual way.

The President then called upon Mr. Howard Long to present his paper, entitled "Diffusion and Shadows," which was illustrated by lantern slides and demonstrations. On the motion of the President, a cordial vote of thanks was passed to Mr. Howard Long for his interesting paper, and to the E.L.M.A. Lighting Service Bureau for their hospitality. (The resources of the Bureau proved very helpful in illustrating certain points mentioned in the paper, for example, the effect of a directional component in revealing the nature of embossed, glossy, and textile materials, and the influence of the nature of lighting fittings and their spacing on diffusion of light.)

An interesting discussion followed, in which the following took part: Dr. Konrad Norden, Mr. E. W. Murray, Lieut.-Colonel Kenelm Edgcumbe, Dr. J. W. T. Walsh, Mr. J. M. Waldram, Mr. J. S. Dow, Mr. T. N. Riley, Mr. W. G. Raffé, Mr. H. Lingard.

The President expressed the pleasure of the Society in having present Dr. K. Norden, who had travelled over from Germany specially in order to open the discussion.

Mr. Howard Long briefly replied to the discussion and the meeting then terminated.

Forthcoming Events

March 9th. Dr. S. English on **Some Aspects of the Street Lighting Problem,*** and Mr. R. Maxted on **The Representation of Lantern Characteristics** *(General Meeting of the Illuminating Engineering Society at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1.)*; **6.30 p.m.**

March 16th. Annual Dinner of the Illuminating Engineering Society *(at the Trocadero Restaurant, Piccadilly, London, W.1)*; **6.45 p.m.** for **7.30 p.m.**

March 24th. Discussion on **Special Problems in Industrial Lighting** *(Meeting of the Industrial Lighting Section of the Illuminating Engineering Society at Magnet House, Kingsway, London, W.C.)*; **6 p.m.**

April 6th. Visit to the **Kodak Research Laboratory, Wealdstone,** where a paper reviewing certain applications of photometry in relation to photographic processes is in prospect *(Arranged by the Photometry Section of the Illuminating Engineering Society)*; **6 p.m.**

**Dr. English's paper is to be read again at a meeting of the Local Section of the Illuminating Engineering Society in Dublin, on March 23rd.*

Applications for Membership.

At the General Meeting of the Society, held on February 23, the names of the following applicants for membership were presented:—

Elections Pending.

Corporate Members:—

Batson, H. G.....23, St. Peter's Road, Handsworth, Birmingham, 20.

Brookes, F. J. C.....Mimosa, The Avenue, Sunbury-on-Thames, Middlesex.

Chalmers, Mrs. Pender.....The British Thomson-Houston Co., Ltd., Crown House, Aldwych, London, W.C.2.

Hetherington, A. F...The Gas Light and Coke Company, Horseferry Road, London, S.W.1.

Hime, M. W.....Lighting Service Bureau of Scotland, 29, St. Vincent Place, Glasgow.

Horsfall, A. V.....The Gas Light and Coke Company, Horseferry Road, London, S.W.1.

Noakes, Miss D.....11, Montague Road, Richmond, Surrey.

Associates:—

Ansell, K. W.....49, Grosvenor Road, Muswell Hill, London, N.10.

Pattern, Nathan van..Stanford University, California.

Shanahan, H. F.....Electricity Works, Blackpool.

Sun, J. H.....11, Sheriff Road, Rugby.

Elections Completed.

At this meeting the names of those announced on January 12, which were published in the issue of the Transactions (Vol. II. No. 2, p. 18, February, 1937), were read again, and these applicants were formally declared members of the Society.

Silver Jubilee Commemoration (1934) Award

Members are reminded that the above award (consisting of Five Guineas and a Certificate recording the award) is available annually for a member of the Society of any class under the age of twenty-six years.

The qualification for the award may be: (1) The presentation in writing to any approved Technical Society or Association of a paper dealing with illuminating engineering; (2) the design or construction of a novel instrument or appliance for use in connection with any application or research concerning illumination; or (3) the carrying out of an investigation beneficial to illuminating engineering.

Applications for the award, which should be accompanied by evidence of the fulfilment of one of the above tasks, should reach the Honorary Secretary by the end of June next.

NOTES ON RECENT MEETINGS AND EVENTS

Informal Social Evening.

A new departure on February 17 was the informal social evening held at St. Ermin's Hotel (Westminster), which was attended by about 230 members and friends.

Whilst members were assembling for light refreshments a musical programme was provided. Subsequently a burlesque lecture, illustrated by ingenious and amusing experiments, was delivered by "Professor Hoodlesnoop" (Mr. G. H. Wilson), entitled "The Production of Dark."

After a brief interval, "Lumens at Law" (a mock trial dealing with an alleged case of industrial injury arising from inadequate lighting), and produced by Miss Vera Norvick, was performed—the jury, empanelled from the audience, having as its foreman the President of the society.

Both items proved to be very entertaining and skilfully worked out, and were much enjoyed by members present, on whose behalf a warm vote of thanks was moved by the President to all who had contributed to the success of the evening.

The thanks of the Society are due especially to the president and Mr. W. J. Jones, who undertook the supervision of the programme; to Miss Vera Norvick and all those who took part in the play; to Mr. G. H. Wilson for his lecture; and to Mr. R. O. Ackerley, Mr. J. W. Howell, and other members of the society who shared in the preparations for the evening.

Industrial Lighting Section.

Opening Meeting on February 9.

The opening meeting of the newly formed Industrial Lighting Section took place on February 9. On the invitation of the Gas Light and Coke Company, the meeting was held at Watson House, and those present were afforded an opportunity of inspecting the laboratories, where much of interest was seen.

After Mr. C. A. Masterman had addressed a few words of welcome to the visitors, the president expressed the thanks of the society to the Gas Light and Coke Company for their hospitality, and to Mr. C. A. Masterman, Mr. F. C. Smith, and other members of the staff for the great trouble they had taken in preparing for the visit.

The chair was then taken by Mr. R. O. Ackerley, who called upon Mr. H. C. Weston to give an address on "Lighting and Industrial Performance." After a brief discussion and vote of thanks to the lecturer, suggestions for the running of the section were invited from those present. The chairman, in announcing two forthcoming meetings to deal with "Problems in Industrial Lighting" (March 24) and with the "Design of Industrial Lighting Fittings" (April 21), expressed his satisfaction at the good response that had already followed invitations to join the section. Those interested are advised to get in touch with the honorary secretary of the section, Mr. J. W. Howell (2, Savoy-hill, London, W.C.2).

Photometry Section.

Meeting on February 22.

A meeting of the Photometry Section took place, on the invitation of the General Electric Company, Ltd., at their Research Laboratories at Wembley, on February 22.

After members had had an opportunity of inspecting some of the photometric laboratories, the party assembled in the library to hear a talk by Mr. G. T. Winch on "Some Practical Aspects of Precision Photometry."

Mr. C. C. Paterson, Director of the G.E.C. Research Laboratories, conveyed a welcome to the party, and, on the motion of the President, a vote of thanks to him and to the company for their hospitality was carried with acclamation.

Mr. Winch's address was illustrated by a series of effective demonstrations showing, in a most practical manner, the influence of small changes in the equipment or adjustment of apparatus in causing appreciable errors. The demonstrations were evident to the entire audience, and would have been impossible without the skilful use of photoelectric appliances.

A keen discussion followed, in the course of which general appreciation of the efforts of Mr. Winch and his assistants was expressed.

Meeting of Dublin Local Centre.

On February 18 a meeting of the Dublin Local Centre took place in the library of the Institution of Civil Engineers, when a joint paper on "Electric Discharge Lamps and their Applications" was presented by Mr. H. B. Ruff and Mr. R. Maxted. In the course of the paper the spectra of various types of discharge lamps and their influence on colour charts was illustrated, and the efficiency attainable was discussed. The processes that occur in the striking of the arc were shown experimentally. Finally, the effect of ultra violet light in the spectra of such lamps on fluorescent powders was demonstrated.

Subsequently Mr. R. Maxted, by the aid of lantern slides and model roads, illustrated the effects of correct street lighting.

A vote of thanks to the lecturers was moved by Mr. E. J. Davidson and seconded by Mr. J. Gallagher, and, on being put to the vote by the chairman (Mr. F. X. Algar), was carried with acclamation.

Colorimetry and its Relation to Photometry.

The Council has approved the proposal of the Committee of the Photometry Section that the address on the above subject delivered by Mr. J. Guild at the sectional meeting on November 24, 1936, should be reproduced in the Transactions of the Society. Mr. Guild's address on that occasion was greatly appreciated, and a desire has been expressed that it should be placed on record for the benefit of members as a whole.

ELECTION OF OFFICERS AND COUNCIL

SESSION 1937-1938. OFFICIAL NOTICE

IN accordance with the procedure specified in the Articles of the Society, a list of existing Officers and Members of Council, of vacancies occurring and of duly qualified persons nominated by the Council for vacancies about to occur in the offices of President, Vice-Presidents, Hon. Treasurer, Hon. Secretary, and Ordinary Members of Council, is presented below for the information of the Members of the Society.

In the event of any Members desiring to put forward other names, the Council will be pleased to receive such nominations, which should be made in accordance with the following rule (Article 48):—

> "After the issue of the Council's list, and not later than the 15*th day of April* next following, any ten Members (but no more than ten) may nominate any other duly qualified person to fill any such vacancy by delivering such nominations in writing to the Hon. Secretary, together with the written consent of such person to accept office if elected, but each such nominator shall be debarred from nominating any other person for the same office at such election."

Present Officers and Members of Council

President*:—*Mr. A. Cunnington, B.Sc., M.I.E.E.

***Past Presidents*:—**

Mr. A. P. TROTTER, M.INST.C.E.
Sir JOHN HERBERT PARSONS, C.B.E., F.R.S.
Mr. D. R. WILSON, C.B.E.
Mr. C. C. PATERSON, O.B.E., M.I.E.E.
Dr. J. W. T. WALSH, M.A., D.SC., M.I.E.E.
Lt.-Col. K. EDGCUMBE, T.D., M.INST.C.E., M.I.E.E.
Sir FRANCIS GOODENOUGH, C.B.E.
Lt.-Com. HAYDN T. HARRISON, M.I.E.E., R.N.V.R.
Mr. C. W. SULLY.
Mr. H. HEPWORTH THOMPSON.
Mr. A. W. BEUTTELL, M.I.E.E.

***Vice-Presidents*:—**

Mr. S. B. Langlands (1934)
Dr. S. ENGLISH (1935)
Mr. PERCY GOOD (1936)

***Members of Council*:—**

Mr. R. O. ACKERLEY (1936)
Mr. W. A. Bishop (1934)
Mr. H. Buckley (1934)
Mr. D. CHANDLER (1935)
Mr. J. G. Clark (1934)
Mr. Justus Eck (1936)*
Dr. W. M. HAMPTON (1935)
Mr. George Herbert (1934)
Mr. W. J. JONES (1936)
Mr. H. LINGARD (1935)
Mr. HOWARD LONG (1936)
Dr. R. J. LYTHGOE (1936)
Mr. A. R. MCGIBBON (1936)
Prof. J. T. MACGREGOR-MORRIS (1936)
Mr. Waldo Maitland (1934)
Mr. E. W. MURRAY (1936)
Mr. F. W. PURSE (1935)
Mr. W. R. RAWLINGS (1935)
Mr. A. B. Read (1934)
Mr. James Sellars (1934)
Mr. F. C. SMITH (1935)
Mr. J. M. WALDRAM (1936)
Mr. H. C. WESTON (1936)

* *Retired* (1936)

***Hon. Secretary*:—*Mr. J. Stewart Dow* (1928)**

***Hon. Treasurer*:—*Mr. E. Stroud* (1936)**

Nominated by the Council to fill Vacancies

***President*:—**Dr. S. ENGLISH.

***Vice-Presidents*:—**

Mr. F. C. SMITH.
Mr. W. J. JONES.

***Members of Council*:—**

Mr. A. M. BELL.
Mr. B. F. W. BESEMER.
Mr. H. BRIGHT.
Mr. J. F. COLQUHOUN.
Col. C. H. SILVESTER EVANS.
Mr. C. A. MASTERMAN.
Mr. J. S. PRESTON.
Mr. L. M. TYE.
Mr. G. H. WILSON.

***Hon. Secretary*:—**Mr. J. S. DOW.

***Hon. Treasurer*:—**Mr. E. STROUD.

The names in italics are those of retiring Officers or Members. The date in parentheses after each name indicates the date of election to Office or Membership of the Council.

SOME IMPORTANT CONSIDERATIONS IN COLLIERY LIGHTING

by J. W. HOWELL, D.L.C., A.M.I.E.E.
(E.L.M.A. Lighting Service Bureau.)
(Member)

(Paper read on Tuesday, January 12th, 1937).

The lighting of mines is certainly one of the most difficult problems in industry. In surface works acid fumes are often present, whilst underground the presence of inflammable gas, the transient nature of the workings, and the almost negligible reflection from surfaces constitute a formidable array of obstacles to the illuminating engineer.

Surface Lighting.

Good lighting at the pithead and in surface workings is as essential as that underground, and should be of such a character that a reasonable amount of illumination properly controlled is always present. It must not be forgotten that safety below often depends upon the efficient operation of surface plant, and lighting faults may seriously jeopardise life below ground. The Coal Mine General Regulations (Lighting), 1934, requires that effective provision shall be made for securing and maintaining sufficient and suitable lighting in every place above ground in which persons regularly work, and that all units, etc., shall so far as is practicable be kept reasonably clean.

Until recently artificial illumination in the majority of pithead shops has been very poor, and maintenance practically nil. This has resulted in poor lighting and dirty windows. Owing to the prevalence of dust and acid fumes it is advisable in many cases to use specially treated fittings to avoid rapid deterioration. Apart from this special consideration much of the surface lighting is identical with general industrial practice.

Boiler Houses

The boiler house presents one of the easiest problems in lighting, the atmosphere being relatively free from dust, etc. The lay-out of the plant usually allows the use of a general overhead system with reflectors of the standard dispersive type, but it might be necessary in the case of narrow firing aisles or switching panels to supplement the general system with reflectors either of the prismatic or elliptical angle type. The illumination should be in the region of 5 to 10 foot-candles.

The lighting of wagon roads presents a more difficult problem, for owing to the low head room available and the considerable amount of dust present, open type reflectors are generally unsuitable. Reasonable illumination must be present to enable workers to operate loading chutes. Bulk-head fittings having a wide lateral light distribution are found satisfactory for this purpose, although under certain conditions totally enclosed projectors will be found advantageous. They have a higher efficiency than the bulk-head fitting and would obviously be used where possible. An illumination of not less than 2 to 4 foot-candles should be aimed at.

Picking Belts.

It has been found from experience that colour correction of the light is necessary for most types of coals, and in some cases the "daylight blue" lamps have been used successfully for this purpose. Many coals, however, are difficult to pick even with this correction, and consequently fittings provided with colour correcting visors have been used. Until recently this was the limit of assistance which could be given, but the advent of the high-pressure mercury electric discharge lamp, with its special light characteristic, has brought about a radical change in picking belt lighting. Excepting in isolated cases this type of lighting will be found the most suitable. Apart from the advantage claimed for the colour of the light, the high luminous efficiency of the electric discharge lamp enables much higher illumination levels to be reached from the same lighting points and for the same current consumption. Picking belts should have from 15 to 25 foot-candles of illumination.

TABLE I.

Approximate Lumen Ratings, Etc., Of High Pressure Mercury Vapour Electric Discharge Lamps.

Watts.	Initial Lumens.	Lumens per Watt.	Overall Length m/m.	Outer Bulb Diameter m/m.	Cap.
150	4,800	32	230 ± 15	43 ± 4	E.S.
250	9,000	36	290 ± 10	50 ± 2	G.E.S.
400	18,000	45	325 ± 15	50 ± 2	G.E.S.
300	6,300	21	Containing Tungsten Filament.		G.E.S.
500	12,500	25	Containing Tungsten Filament.		G.E.S.

Yard Lighting.

This can only be made effective by using some form of floodlighting. It is true that some collieries still use centrally suspended fittings over rail lines, and the management contend that it is useless to attempt lighting by proper units owing to rapid corrosion. For this reason the shades used oftentimes do nothing more than protect the lamp from rain, etc., and in some cases are hammered out of sheet-metal at the colliery itself. Such equipment is a complete failure so far as light distribution is concerned. Projectors which are impervious to dust and moisture are a practical solution. These should, obviously, be of a non-ventilated type, and provided machined housings are fitted, they will prove sufficiently airtight to prevent the entry of acid-laden air, which would cause deterioration of the reflecting surfaces.

Rail sidings and yards should be lighted to a level of not less than 0.5 to 1 foot-candle.

Electric-discharge lamps when used should be so mounted and screened that no confusion is likely to occur with railway signals, this type of lighting proving the most economical and effective method for yards and sidings.

Underground Illumination.

The standard of illumination below ground is deplorably low, and in spite of the easing of the regulations (1) the latest Mines Inspectors' reports indicate that, generally speaking, mine engineers have not availed themselves of the opportunity to improve lighting conditions. If the conditions at present existing can be improved, a considerable reduction in accidents will result. Mains lighting can be shown to be an economical proposition, and there is no logical reason why extensive developments should not occur in this field. The existing regulations are indicated graphically in Fig. 1.

The majority of mines rely entirely on the miner's handlamps or cap lamps for illumination purposes below ground, which even with the improved lamps now available falls far short of an ideal system. Excessive contrasts are created, which inevitably interfere with efficient visibility. Lighting of this kind has had its deleterious effect, the weight of authoritative opinion, indicating that it has seriously contributed to the condition known as nystagmus. It is seldom realised that the bulk of disablement through diseases in industry occurs in mines, and that no fewer than 48.2 per cent. of the cases in mines notified in 1934 were due to nystagmus (2). The number of cases suffering from this disease in that year was 7,174, and adding to the 1,745 new cases notified during 1934 the total reached 8,919. Thus it is apparent

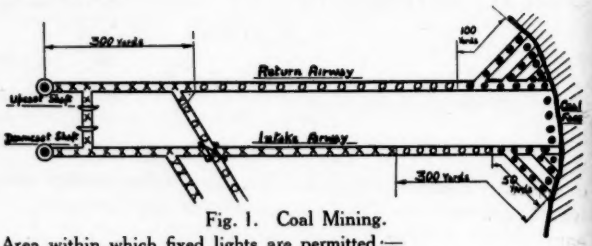

Fig. 1. Coal Mining.
Area within which fixed lights are permitted:—
(Coal Mines Gen. Reg. (Lighting) 1934. Part II. Reg. II.)
(1) Subsection (a) and (b).....X
(2) ,, (c).....O
(3) Special Regulation (d).....●

that a thorough investigation is warranted, and the installation of the best of modern equipment a vital necessity.

Where better lighting has been installed there has been a marked decrease in the incidence of this complaint. Concentrated sources of light—such as are derived from portable lamps—are in violent contrast to the dark surroundings and give rise to acute glare, causing disability and discomfort. Both direct and reflected glare are present in mines. Direct glare occasioned by the use of unshaded, inadequately shaded, or ineffective diffuse sources of light located within the line of vision is commonly present. This is true even where overhead mains lighting has been introduced, for often clear lamps are used in clear well glasses totally unscreened. Reflected glare is present due to the reflection of the light source from the coal surfaces themselves. There can be no doubt that the time is ripe for a vigorous drive to secure better lighting conditions underground.

Haulage Roads.

The recent requirements of the Mines Department should do much to improve conditions. From a visual standpoint the advantages of whitening the top and sides of haulage roads will materially assist in securing a far better reflection factor and is becoming widely appreciated. Whitening is usually carried out in built roadways by whitewashing, but if this is done on earth or bind sides and roof, considerable cracking, with consequent falls, will occur. Recourse is, therefore, made in rough roadways to stone dusting.

Existing statistics reveal considerable benefits gained from use of mains lighting in haulage roads and other parts of the mine as permitted by the General Regulations. Apart from any other consideration the question of safety is extremely important. A considerable proportion of accidents are occasioned here and it is logical to assume that with

the installation of effective lighting these would be materially reduced. In the Sneyd Colliery (3), for example, a comparison of haulage road accidents showed that 50 per cent. less had occurred since mains lighting was installed. The necessity of speedily recognising the presence of moving conveyances is evident. In addition, in the above colliery, the metals which were previously in darkness and formed an easy point for stumbling can now be easily seen and faulty rails readily detected. It is submitted, therefore, that a constant, evenly distributed, illumination is much more conducive to good lighting than the use of individual miner's lamps.

In view of the restrictions on head-room the type of fitting used will obviously be governed by its projection. The bulkhead type of fitting is eminently suitable for such work, when fitted with a prismatic glass, the most suitable having a smooth exterior which greatly facilitates cleaning. The size of lamps is usually 40 or 60 watts. This type of fitting has a big advantage over the well glass type; firstly because of the reduced projection, and secondly, because of the removal from the normal line of vision of the light sources.

Coal Face Lighting.

It is exceedingly difficult to convince users in this as in other industries, of the necessity of breaking away from hitherto accepted standards of lighting. From a visual standpoint the mains lighting system is superior to any other for it can be made relatively glare free. As is well known, glare is partly dependent on the relative brightness of the light source and the brightness of the surrounding area.

Under daylight conditions, not only the working point but also the whole of the neighbourhood is illuminated, giving similar surface brightnesses, whilst oftentimes by bad artificial illumination the working point is illuminated only and the neighbourhood left in darkness. This condition prevails under portable lamp lighting, the miner's lamp giving a very small illumination in its immediate neighbourhood. The eye then operates under distinctly unnatural conditions, and some authorities assert that eye troubles are consequently increased.

The Effect of Difference of Brightness.

The experimental work of Lythgoe (4), show that the eye operates most efficiently when the object viewed is surrounded by a field of vision, the brightness of which is approximately that of the object itself. Visual perception improves slowly as the brightness of the surrounding field is raised to that of the object and then falls away rapidly.

In this particular test, values have been used which approximate to suggested values at the coal face. The illumination on the test object was 0.44 foot-candles, and it is seen from Fig. 2 that as the illumination of the surrounding field approaches this figure, maximum visual acuity is reached. As the surrounding field brightness increases over the brightness of the test object it rapidly falls. Conditions which promote even field brightness are therefore superior from a

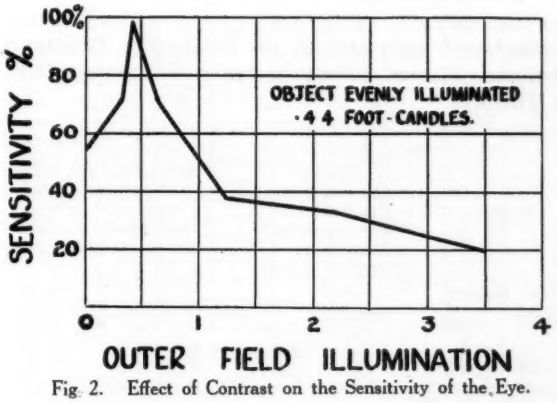

Fig. 2. Effect of Contrast on the Sensitivity of the Eye.

visual standpoint to those where heavy contrasts in brightness are present, as is the case when portable lamps are used.

Let us resolve this into practical figures. Assume that lamps in both cases are at a distance of five feet from the coal face. A 4-volt lead acid accumulator lamp gives approximately a light output of two candles, and will give 0.08 foot-candles at the coal face. Assuming a reflection factor of 8 per cent. for the coal face the brightness of the coal surface in equivalent foot-candles equals 0.0064 or 1.41×10^{-5} candles per square inch. A low voltage 40-watt lamp gives approximately thirty-seven candles which when surrounded with an opal well glass gives approximately 1.18 foot-candles at the coal face, the corresponding brightness being 2.08×10^{-4} candles per square inch.

The story, is however, not yet complete. The filament of a clear miner's lamp has a brightness of around 1,000 candles per square inch; using a pearled funnel glass, this is reduced to approximately fifty candles per square inch. On the other hand, the 40-watt lamp, on account of its higher light, can be enclosed in an opal well glass, so that the resultant brightness of two candles per square inch is obtained. The mains lighting, therefore, gives higher field brightness with less glare. These results are summarised in Table II.

It is worth while examining the relationship between the permissible brightness of the light source and its background further. Nutting (12) showed that if the background brightness was increased ten times, the permissible increase in the brightness of the light source would be approximately double, if eye comfort under the two conditions were to remain constant. This could be demonstrated as follows:—

Two backgrounds are used, one of a brightness approximately 0.8 and the other 8 candles per square inch. In front of this are suspended two light sources of a brightness of 50 candles per square inch. A much greater sense of discomfort is experienced

TABLE II.

Approximate Comparison or Brightness Contrasts between Miners' Safety Lamps and General Mains Lighting.

1	2	3	4	5	6
System.	Filament, bulb, or fitting brightness in candles/sq. in.:	Light output of lamp approx.: C.P.	Illumination at coal surface 5 ft. away in F.C.	Brightness of coal surface in candles per sq. in.:	Brightness ratio between Column 2 or 5.
Clear Battery Lamp ...	1000	2	.08	1.41×10^{-5}	7.1×10^{7} to 1
Lamp inside pearled funnel	50	2	.08	1.41×10^{-5}	3.55×10^{6} to 1
40 watt lamp with opal well glass, 20% absorption ...	2	37	1.18	2.08×10^{-4}	9.62×10^{3} to 1

under the less bright background condition, but if we reduce the brightness of the corresponding light source to approximately 25 candles per square inch, that is, by half, it is now found that the two conditions are comparable. These conditions agree with Nutting's theory. Fig. 3 gives this relationship.

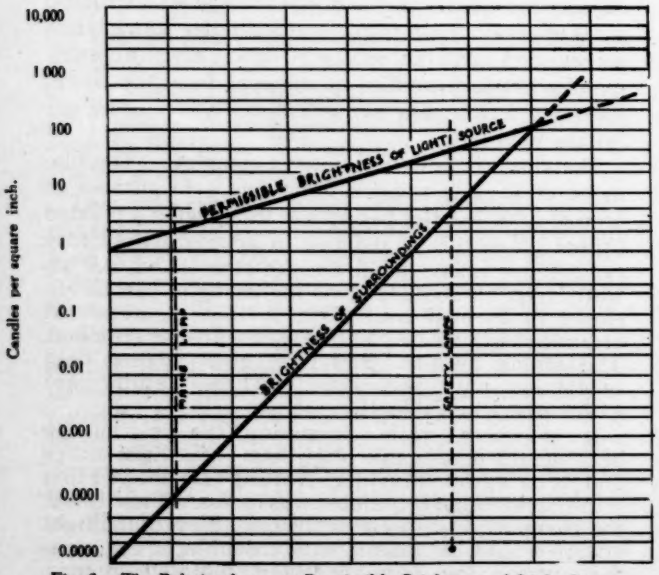

Fig. 3, The Relation between Permissible Brightness of Light Sources and Brightness of Surroundings.

It is seen that for a background brightness of 1 candle per square inch, the limit of comfort is reached when the brightness of the light source is approximately 30 candles per square inch, or a contrast of 1 to 30. Applying these results to the present problem, it is found from Table II. that the coal-face brightness under safety-lamp illumination is of the order of 0.0000141. Reading the corresponding point from Fig. 3, the fitting brightness should be about 1.2 candles per square inch, but is actually 50, giving rise to acute glare conditions. Now, taking the mains system with a background brightness of 0.000208, the corresponding fitting brightness shown by the graph is 2.5 candles per square inch, which is slightly higher than that actually given by the fitting. It is thus evident that much better seeing conditions exist under the mains lighting than is obtainable with safety-lamp illumination.

The Effect of Sustained Inadequate Field Brightness on the Eye.

Under normal conditions the eye is constantly moving, focussing the image of the object viewed on to the fovea. This is the position giving the highest visual acuity, and in addition serves to focus and fixate the line of vision. If, for any reason, the fovea becomes desensitised, the person so affected can neither see detail distinctly nor fix his vision on a point. Professor Sharpley suggests (5) that the continuance of such conditions over long periods will cause the normal functioning of the fovea to desist and gives rise to the majority of nystagmus.

Symptoms of this complaint are almost invariably present in cases of colour blindness, irrespective of occupation, where as already explained the operation of the fovea is not sustained, causing oscillation of the eyeball and an endeavour on the part of the subject to avoid bright lights with inability to see clearly thereby. The average age of mine workers, when this disease has become serious enough to prevent further occupation, is about 42 years, and has occurred after about twenty-six years underground (6). It follows, therefore, that to minimise these troubles with the consequent severe loss of skilled labour, the necessary objective brightness (coal face brightness) will need to be 0.01 candles per square foot if all workers are to be sure of the use of foveal vision (5).

In addition to the physical reaction, the equally important psychological effect of lighting must not be overlooked. The miner's task is one which means a certain amount of enforced solitude, with a consequent lowering of efficiency. By dispelling the darkness and illuminating the whole of the working area, this effect of solitude is overcome, the increased illumination carrying with it a much happier reaction.

Professor Statham puts forward an illumination value on the coal face of at least 0.4 foot-candles (7).

Accidents.

Recent tests at the Steetley Colliery (8) have proved that a reasonable degree of illumination was obtained when a wattage of 7.8 per linear yard of coal face was used. The average distance at which the lamps are hung from the coal face is usually about 4 ft. 6 in.

Direct evidence has been obtained at this colliery of the beneficial effect of improved lighting on the accident rate. The number of accidents reported per month since the introduction of machine mining at the coal face has been recorded and is shown in Fig. 4.

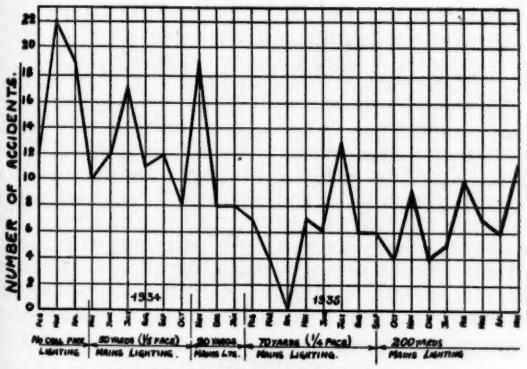

Fig. 4. Accident Chart (Steetley).
All reported accidents together with extent of coal face lighting.

The accident chart covers a total of 100 men working at the coal face in three shifts, and all of these, therefore, were affected by the improved illumination. Referring to the graph, it will be seen that without mains lighting at the face during March, 1934, the total number of reported accidents was twenty-two, whilst with four-fifths of the coal face lit from the mains, this had dropped, in the month of October, 1935, to four. This shows a reduction in the accident rate of 82 per cent. The average cost of compensation at the coal face has been £2.85, the number of cases per month having fallen from six and a half to one and a half, representing a saving of 0.3d. per ton of coal raised, which is more than the combined capital and running costs of the new installation, less labour charges.

Production.

The most comprehensive test of mains lighting is undoubtedly that conducted at the Wenceslaus Pit (Germany) in 1927-29 (9). In the following curves an average performance of four months prior to interfering with the old lighting system has been taken as a normal performance under safety lamp lighting. The period from April until July, 1927, called hereafter the transition period, showed a gradual change over from the safety lamp to the final installation of 150-watt lamps spaced approximately five yards apart. The declines recorded in March and October, 1928, were caused by labour and mechanical troubles, and, therefore, are not indicative of normal production.

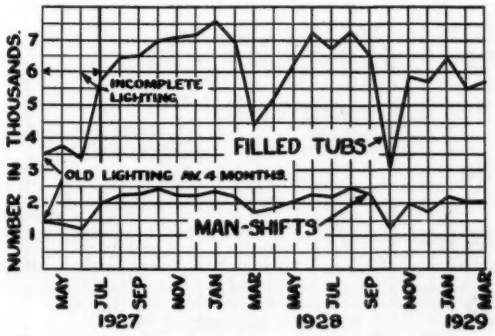

Fig 5. Number of Filled Tubs and Man-Shifts with New Lighting System compared with Old Lighting System.

Fig. 5 shows the numbers of tubs filled and man-shifts worked. Under the old lighting a number of 1,423 man-shifts were required to raise 3,475 tubs of coal, or an average per man-shift of 1.87 tons. During the transition stage an average of 4,330 tubs were raised in 1,531 man-shifts, or an average per man-shift of 2.11 tons. Now, taking an average figure for the complete mains lighting, a considerable advance has been recorded, showing 2.32 tons of coal raised per man-shift, an increase in production of 25 per cent. This is shown in Fig. 6.

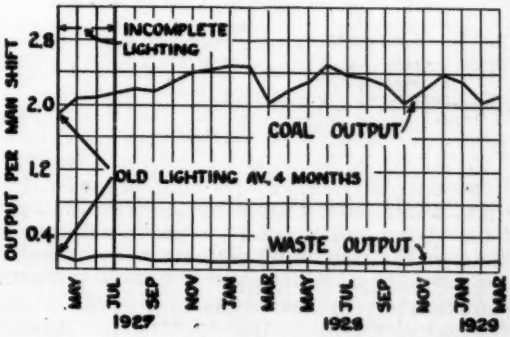

Fig. 6. Clean Coal Raised per Man-Shift under Old and New Lighting Systems.

A further interesting point is that the proportion of good coal brought to the surface has increased, whilst

at the same time the waste content has decreased by 142 tons in a total haulage of 5,040 tons.

In fact at one period, June, 1928, a maximum output was reached at 2.54 tons per man shift. Strangely enough at this period, the waste content was at the lowest figure, being only 3.5 per cent. of the total raised. Fig. 7 gives these results in terms of percentage increase or decrease of raised coal or slag, etc. In addition to the 25 per cent. increase in production already recorded, this particular mine is very subject to fire-damp, the presence of gas limiting the shift underground to 6 or 6½ hours. If, therefore, the full shift had been worked a further increase of 20 per cent. would have been recorded.

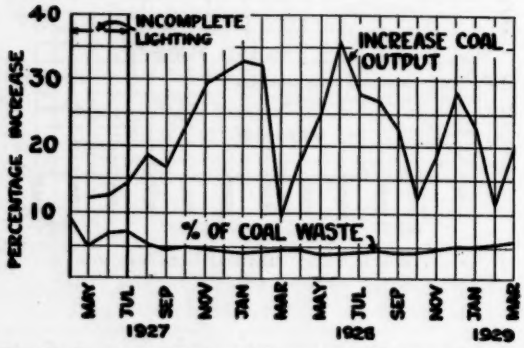

Fig. 7 Increase in Coal and Decrease in Waste as Percentage under New Lighting.

TABLE III.

Quantities raised in Wenceslaus Pit under Old System of Safety Lamps as compared with New System of Mains Lighting. Per Month of 2,170 Man Shifts.

Total Coal and Shale raised in Tons.	Shale. Tons.	Shale Contents of Total. %
	Old System.	
4450	391	8·8
	New System.	
5040	249	4·7
An increase of 590 tons.	A reduction of 142 tons.	

Under the old system 8.8 per cent. of the total haulage was waste, whilst ignoring the transition period and the strike and breakdown periods, the average waste over the remaining eighteen months was only 4.7 per cent., or a reduction of almost 50 per cent.

Unfortunately, it has not been possible to obtain such conclusive data in this country, for apparently no records have been kept with regard to production. For example, in the report of the Steetley Colliery (8) tests it states that "There has been some increase in the rate of stripping and filling, but as the pit enjoys conditions which allow clean filling, so far as dirt is concerned, there has been no appreciable reduction in that direction. Roof conditions and affairs generally at the face are easy to observe."

Similarly with tests at Langwith (10), the report states that although no data are available "A saving is confidently expected and the small percentage per man shift would cover the cost of installation and, together with the saving in compensation, would amply repay the capital costs."

For the Norton Pit (11) it is stated "That right from the commencement of the tests the effect at the working face was most marked, the colliers being enthusiastic in their appreciation of the tests."

Although it is not possible to give actual figures to show the improvement in coal filling, a great improvement was recorded in the latter case from the installation of pneumatic electric lamps. Whereas before their use complaints of dirty coal were numerous, these complaints have now ceased. Similar experiences have been obtained at other collieries where dirt filling has been particularly troublesome. In one case complaints became so serious that special permission was sought and obtained to test out various lighting systems. The dirt and coal appeared so much alike under safety lamp lighting that it was almost impossible to recognise which was coal and which dirt. The mains system was installed with beneficial results at this colliery, proving the inadequacy of the small candle-powered light source for this work. It is interesting to note that every other conceivable method of coal cleaning was tried before varying the lighting, including expensive coal cleaning plant, but all proved uneconomic in operation.

Economics.

It is evident that the adoption of a mains lighting system at the coal face will be economically controlled by the thickness of the coal seam. With good roof conditions the minimum would be from 2 ft. 9 in. to 3 ft. thick, under which, owing to the very limited spread of illumination and the lack of space for fixing, the proposition would be uneconomical.

Formulae to determine the size of lamps and their spacing have been propounded by J. C. Mitcheson as follows:—(13)

Spacing of lamps (in yards) = (2 × thickness of seam in feet) − 1.

Size of lamp (in watts) = (spacing of lamps in yards)^2.

As an example a 5-ft. seam may be taken. Then the lamps would be spaced at a distance of (2×5) − 1 yard = 27 ft., and the lamps wattage = $9^2 = 81$ watts. This enables the results to be expressed in terms of wattage per sq. ft. of coal face = $\frac{81}{5 \times 27}$ = approximately 5-9ths watt per sq. ft. It would appear that this figure is fairly accurate for referring to the tests of Atkinson and Allsop at Steetley (8); it was found that 750 watts per 100 yards of face gave a reasonable degree of intensity of illumination. This latter figure actually works out slightly higher at 2-3 watts per sq. ft. of coal surface. It now remains to decide whether it is more suitable to use lamps of the

60-watt type spaced at approximately 27 ft. apart, or to use 40-watt fittings more closely spaced. The slide shows a photometric survey taken on a coal face, from which it is seen that using 60-watt fittings a distinct peak in the readings occurs opposite each fitting which, incidentally, was spaced 27 ft. apart. If, however, 40-watt fittings are adopted the distribution would be that indicated by the dotted line, which has been superimposed on the actual illumination curve. Whilst a more uniform illumination would be given with 40-watt lamps retaining the same wattage per foot run, the distance between fittings would be approximately 18 ft. according to Mitcheson's formulae. To affect this advantage, however, the capital cost entailed and lamp renewals rise proportionately, and it is a conjectural whether this is compensated for by the better distribution.

Consider the economics of practical tests:—

1. 150-watt lamps at a pressure of 70 volts—Wenceslaus Pit (Germany).
2. 60-watt lamps at pressures of 110 and 25 volts—Steetley Pit.
3. Pneumatic lamps using 30-watt 12 volt automobile lamps—Langwith and Norton Pits.

Considerable experience has been gained in Germany with mains lighting at the coal face, some 200 pits being illuminated in this manner. Full economic details are available in so far as the Wenceslaus Pit is concerned, particulars of which are given below, British equivalents being substituted:

	Tons.	Cwts.	Qtrs.
Output per man shift using Mains lighting during December	2	8	1
Output at same face with safety lamps during April	1	16	0
Increase per man shift due to better lighting	—	12	1

Monthly cost of new installation including depreciation, interest, lamp replacements, increased current, etc.	=	£25
Average number of man shifts per month	=	2,170
Average coal raised per man shift by old lighting	=	1·87 tons
Average increase per man shift by better lighting	=	9 cwt.
Average wage per man shift	=	9·1 shillings
Increase per month of raised coal under better lighting = 2170 × 9/20 tons ...	=	976 tons
Number of man shifts required to raise this under the old lighting—976/1·87	=	522
Cost to raise at 9·1 shillings per man shift	=	£238
Cost of new installation	=	£ 25
	SAVING =	£213

In order that suitable comparisons may be made the data have been resolved into common form in the case of all tests which are analysed as follows:—

TABLE IV.

General Particulars.

PIT.	WENCESLAUS.	STEETLEY.	LANGWITH.	NORTON.
Year of Test	1927/9	1934/6	1936	1936
Output per month in tons	5,100	12,600	11,400	4,500
Lighting hours per annum ...	7,500	5,000	4,800	5,750
Depth of seam in feet	5·75	4·17	4·5	7·5
Capital Cost	£250	£551	£360 air mains £800 Inbye compressor	£75
Current cost per unit ...	0·6d.	0·33d.	—	—
Compressed air per 1,000 cu. feet... ...	—	—	1.5d.	0.75d.

TABLE V.

Annual Costs in Pounds (Sterling).

PIT	WENCESLAUS	STEETLEY	LANGWITH		NORTON
			Air Mains.	Inbye Compressor.	
Depreciation	50	110	72	160	16
Interest ...	15	14	10	20	2
Lamps ...	55	20	18	18	4
Current ...	100	15	—	—	—
Compressed Air... ...	—	—	350	180	44
Labour ...	50	260	60	60	40
Overheads...	25	15	15	15	2
TOTAL ...	295	434	525	453	108

TABLE VI.

Analysis of Lighting Costs Per Ton of Coal Raised in Pence.

PIT.	WENCESLAUS.	STEETLEY.	LANGWITH.		NORTON.
			Air Mains.	Inbye Compressor.	
Lamps ...	0·215	0·0318	0·0316	0·0316	0·018
Current ...	0·392	0·0248	—	—	—
Compressed Air ...	—	—	0·614	0·316	0·196
Labour ...	0·197	0·421	0·105	0·105	0·180
Depreciation & Interest	0·255	0·197	0·144	0·315	0·080
Overheads...	0·908	0·024	0·0263	0·0263	0·009
TOTAL ...	1·157	0·6986	0·9209	0·7939	0·483

Since this test it is found that even using 40-watt fittings and consequently increasing from thirty-eight in the 60-watt case to sixty, a modern installation could be installed on this face for £332, or an annual charge of £66 10s. This reduces the lighting cost for ton of coal raised for depreciation and interest from 0.197 pence per ton to 0.119, and the total to 0.6186, assuring all other costs to remain as before.

Conclusions.

Taking a general survey over the results, the Norton Colliery would appear to be the most economical system; but it must be borne in mind that the seam in this case is 7 ft. 6 in., as against 4 ft. 2 in. for the Steetley Pit. It is obvious, therefore, that if a deeper seam had been present in the last case a much better figure per ton of coal raised would have been obtained. Fairly good comparison is given by bringing the figures on the basis of the 5 ft. seam and is given below:—

TABLE VII.

Type of lighting.	Place.	Assessed cost of lighting per ton of coal raised for 5 ft. seam in pence.
150-watt mains lighting	Wenceslaus	1·157
60-watt mains lighting	Steetley	·582
36-watt pneumatic lighting	Langwith	·827 compressed air from mains.
		·712 Inbye compressor.
36-watt pneumatic lighting	Norton	·724 compressed air from mains with low charge.

Taking into account the big reduction for the cost mentioned under the heading of Accidents in the Steetley Colliery of 0.3d. (8), it will be seen that the best results are obtained in this case. The illumination values are interesting as a further explanation of the high cost of the Wenceslaus installation.

TABLE VIII.

Name of installation.	Vertical illumination in foot-candles on coal face.	Horizontal illumination in foot-candles on floor.
Wenceslaus ...	2·1	2·4
Steetley ...	·12	·07
Langwith ...	·1	·08
Norton... ...	·5	·15

It will be remembered that an illumination of 0.4 foot-candles (7) was suggested for coal face lighting, and, referring to Table 8, readings very much in excess of these were obtained at Wenceslaus, which, together with the high current cost of 0.6d. per unit, and extra cost of higher wattage lamps, undoubtedly account for the high cost per ton of coal raised. If a suitable allowance is made for these charges, results would compare favourably with the other costs. It is estimated that the cost of the safety lamps is about 0.3d. per ton, but in all cases of mains and compressed air electric lighting, even with the higher charges, benefits gained more than compensate for the extra cost involved, especially in accident reduction, saving of skilled labour, and improvement in output and quality.

It is hoped that careful consideration will be given to the benefits of coal face lighting, either direct from the mains or by means of pneumatic lamps, the latter being exempted from the Mines General Regulations, and suitable for use in fiery mines.

It is the author's firm belief that sooner or later handlamps, from an illumination standpoint, will become obsolete, and the improved means of obtaining more light and better distribution will become the accepted system in modern mines.

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DISCUSSION

Mr. F. H. Wynne (H.M. Deputy Chief Inspector of Mines) said that the difficulties encountered in getting anything like good lighting in mines would be realised from what the author had said. That more light was desirable was admitted by everybody concerned, but there were other things to contend with besides merely providing the lighting. The handlamp did not give a great deal of light, and even a light of 2 cp. was a development of recent years. Whilst it might be regretted that colliery managers were reluctant to adopt mains lighting, there must be a certain amount of sympathy with that reluctance, because there were so many factors to be considered by the manager before coming to a decision on the matter. At the coal face there were, in modern mines, coal-cutting machines with trailing cables, and conveyors also with some kind of trailing cables. At the same time, there was only a very

limited space, and into that limited space it was now proposed to introduce some form of mains lighting which would have to be dismantled, removed, and reassembled once in perhaps every twenty-four hours to keep up with the advancing coal face. Further, there was some suspicion with regard to the possibility of sparks from the cable and fittings which might cause an explosion. The risk of sparks from portable lamps was not a serious one, but in the case of mains lighting experience was as yet very limited, and nobody knew exactly what snags were likely to be met with. It should also be remembered that should there be an accident of this sort due to mains lighting, it would kill that method of lighting for years. Perhaps, therefore, it was not surprising that colliery owners and managers were rather reluctant to adopt it. The lighting of roadways was a comparatively simple matter, and it would generally be accepted that better lighting usually led to better work. However, good lighting in roadways was not completely dependent upon the actual lights, for the liberal use of whitewash on the walls was an enormous help. It was true that whitewash was used already to some extent in most mines, but he often wondered why it was not used much more extensively. Experience had shown that it had no deleterious effect on the strata, but rather that its effect, if any, was an advantageous one. However, the question of improved lighting of collieries generally is receiving close attention at the present time and will continue to do so.

In conclusion, he said that he looked forward with confidence to further developments in the near future that would lead to still further improvements in lighting underground in mines. He felt that the possibilities of the application of electricity in this connection had not yet been by any means exhausted.

Mr. G. M. HARVEY (H.M. Deputy Electrical Inspector of Mines) said that the author had dealt very fully with the advantages of face lighting from the mains and with the determination of the most effective form and degree of illumination, but he had not given full value to the difficulties in the way. The well-lighted roadways shown in the slides were not typical even of main roads, and conditions at the coal face were very different.

An average coal face resembled a gallery or corridor 100 yards long, four feet in height, and about three yards wide. One wall was the solid coal and parallel with this were two or three rows of props from three to six feet apart.

Once every twenty-four hours a depth of six feet of the wall of coal was removed and a new set of props erected to support the roof. This entailed the removal of the whole of the face lighting cable and fittings from a position behind one row of props to a new position in front of it. Further, every time an explosive charge was fired in the coal, the lighting equipment in the vicinity of the shot had to be removed or protected from damage.

The almost entire absence of reflecting surfaces meant that only direct illumination was possible, and it was difficult to illuminate at the same time the coal, roof, floor, and waste.

The lamps were necessarily enclosed in glass, which meant that every fitting was a possible source of danger.

Every underground worker had to be provided with a portable hand-lamp, and it was generally regarded by the management as preferable to give him a good one and let that serve to light the working place. The hand-lamp could be placed in any position to suit the worker. In seams less than three feet in thickness, mains lighting was useless as the bulk of the light was obscured by the workers themselves.

A point about roadway lighting was that it had been found advantageous, when a main road was lighted for a length of 900 yards and whitewashed, to continue the whitewashing beyond the point where the lighting ceased, so that the worker's eyes were gradually accustomed to the reduction in illumination before he reached the complete blackness of the working face.

He would be glad if the author would state the voltage required at the terminals of the high-pressure mercury vapour discharge lamps referred to in Table I.

Mr. E. A. HAILWOOD, speaking with regard to mains lighting, said he had been connected with miners' lamps for thirty-seven years, and although mains lighting had been spoken of all that time, not much progress had been made. As one interested in oil-flame lamps, he expressed the view that they offered the best solution, and added that there was available a flame lamp giving 11 candle-power, which weighed no more than a portable electric lamp. There were great advantages in the portable lamp, not the least of which was the reduced risk from explosion of gas. Experiments had also led to the definite belief that an oil flame had a penetrating value 25 per cent. greater than that of an electric lamp of the same candle-power, and, in his opinion, shale was more readily distinguished from coal by means of the oil flame than was the case with illumination from portable electric lamps. In his view the oil-flame lamp lent itself to a great many possibilities in giving better lighting. The figures in the paper relating to German coal mines were dated 1927-29, which was rather long ago. In the case of the Nunnery Colliery in this country, which the author had not mentioned, there had been two years' experience of mains lighting, and the resultant conclusions which appeared were not in accordance with those in the paper concerning other mines.

Mr. C. A. MORTON asked for information as to the extent to which the cap lamp is used by miners, and said that it was probably better from glare considerations than the ordinary portable lamp. He asked how the pneumatic lamp, mentioned in the paper, functioned. He also inquired the voltage between the actual electrodes of the cold cathode tube exhibited. The successful use of sodium light sources for coal picking had been mentioned. It was difficult

to understand this, as the colour rendering from a monochromatic source was likely to be less suited to coal picking than that of a source that was only appreciably deficient in red light.

Mr. HOWARD LONG commented on the fact that so much attention had been paid to lighting underground and suggested that lighting above ground at mines is of equal importance. Referring to the accident chart in the paper, he expressed the view that in dealing with the extremes, as the author had done, he had been rather unwise as quite a good case could be made out otherwise. The German figures did not seem to be very conclusive. It was not surprising that the author had had to go abroad for so many of his figures, as in many industries in this country reliable statistics were almost unobtainable, and even when they were obtained there were so many factors entering into them that they were rather unreliable. The table of relative costs was a novel way of presenting the matter, and the rather surprising result was shown that 2-ft.-candles were not economic, which reflects on the accuracy of the production statistics. Finally, Mr. Long pointed out that there was no reference in the paper to the high frequency system which was demonstrated at the Institution of Electrical Engineers some years ago and for which a great deal was claimed from the safety point of view.

Mr. H. G. BATSON said he was present a short time ago at an interesting experiment at a northern mine, in which sodium lighting was used. The experiment was made in the screening house, and that form of lighting showed up the difference between shale and coal in a remarkable manner without in any way detracting from discrimination between hard and soft coal. A point in favour of these lamps is the small sizes in which they are available, viz., down to 50 watts. Their low brightness and horizontal mounting lend themselves to low mounting heights. The lamp used in the experiment, he had mentioned, was a 65-watt lamp and took the place of a 300-watt incandescent lamp. He saw no reason why these lamps should not be contained in a flame-proof fitting, and, as there was sufficient mechanical robustness to withstand the vibration of the screening plant, such a lamp might also be mounted as an integral part of a coal cutting machine at the coal face and so avoid a separate trailing cable for the light.

Mr. C. HUGHES referred to a development which is taking place with electric discharge lamps for mine lighting. He pointed out that it has been demonstrated that the cold form of cathode lamp, whilst requiring high tension did not reach a dangerous temperature, and that in the event of the lamp itself being broken, the temperature of the electrodes would not be sufficient to fire any gas there might be in the mine. A certain amount of work had already been done in developing such a unit for lighting at the face in mines. A transformer, of course, had to be used for stepping up the voltage and this was incorporated in a special gas-tight case. The two electrodes were placed relatively far apart, and the tube was of the mercury-argon type treated with a fluorescent powder to give some colour correction.

Professor W. H. MCMILLAN (*communicated*) fully agreed that more light was urgently needed in underground workings, and particularly at the working face of the mine. Many would endorse the hope expressed at the end of the paper that, " sooner or later, hand lamps, from an illumination standpoint, would become obsolete." There were, however, many in control of modern and progressive collieries who, whilst realising the advantages of mains lighting at the face, were anxiously looking to the efforts of the illuminating engineer to overcome great obstacles still awaiting solution.

Where conditions were more or less permanent, and little difficulty arose from inflammable gas, where explosives were not extensively used, and where obstacles such as supports, conveyers, etc., were few, mains lighting presented little difficulty, except, perhaps, in the thinner seams. But in most cases the problem bristled with difficulties, and in some of the thicker seams, too, individual lighting was necessary, particularly where coal-getting is carried out " across " and not along the line of the face. For these reasons wattage per sq. ft. of face might often prove of little value as a basis of comparison.

Furthermore, a single portable lamp should not be compared with one mains lighting fitting, for the latter had to serve several workers. Being some distance from the work, or because of shadows from obstacles or unevenness of the face, it might provide a lower illumination than was obtained from the more modern portable lamps. The figures given in columns 4 and 5 of Table II. therefore required modification. The assumed distance of 5 ft. was too great for some portable lamps, and in the case of mains lighting too small for most workers. Recent surveys of illumination at the working face (including the case of the Steetley Colliery) showed that the illumination on the work being done was, on the average, less with mains lighting than where the modern hand and cap lamps were in use.

The results of these surveys (see " Trans. Inst. Mining Engineers ") indicated the need for a more flexible system of mains lighting, providing a larger number of points, and permitting movement of them to suit individual workers. Until such improvements were effected and other obstacles overcome, lighting by portable lamps for individual lighting, with a few lamps distributed at fixed points at intervals along the face for general illumination, would appear to offer advantages.

With further reference to Table II., it should be pointed out that few, if any, lamps would in future have a filament brightness of 1,000 candles per sq. in., as the new lighting regulations required that the light should be distributed in such a way as to avoid excessive contrasts. This requirement neces-

sitated the use of opal or prismatic glasses, which diffused the light and reduced the brightness very considerably.

Mr. WILLIAM MAURICE (*communicated*) remarked that the essential problems of mine lighting began at the working places, where much or little was possible, according to the prevailing conditions. There were many places in which mains lighting could be applied with advantage, but many more where portable hand lamps furnished the best solution. Hand lamps, in conjunction with supplementary illumination from portable reflector lamps, might prove the cheapest and most efficient means of lighting in some circumstances.

The year 1937 should be associated with marked advances in coal mine lighting, not only because of the increased illumination demanded by the Coal Mines General Regulations (Lighting), 1934, but owing to the marked tendency to go beyond statutory requirements. Coal-face lighting from the mains, and its practical equivalent, lighting by compressed air lamps, had been common in Continental coalfields for many years. In Great Britain the use of compressed-air-operated lamps was increasing rapidly, though he believed there would always be mines in which hand lamps were necessary, and would continue to be used.

Mr. Maurice proceeded to summarise some of the drawbacks to mains lighting, such as uneven distribution of light, and strong contrasts, the heavy and cumbersome fittings, and the presence of cables and electrical apparatus at busy places where disturbances are frequent. For face lighting the advantage in regard to safety, practical convenience, and low labour costs rested with compressed-air lamps.

The illumination of haulage roads was another matter. There were many mines in which illumination was continuous from pit bottom to working places, and where roads were reasonably permanent, continuous illumination was usually desirable, though it might not always be economically justified. There was usually no great difficulty in finding appropriate fittings. Persons travelling in either direction should not have to face bright points of light, and fittings should be simple, and easily cleaned. Dirt is deposited rapidly on colliery fittings, and established values should be such as to be adequate after allowance for progressive deterioration. This applied also to surface lighting. It was not unusual to find even office fittings which seemed never to have been cleaned since they were first installed!

In conclusion, Mr. Maurice emphasised the importance of correct placing of lights, especially amidst moving mechanical appliances, which might be just as important as the provision of certain foot-candle values. It was a mistake to regard lighting only in relation to its cost. What was most needed was a more widely distributed change of outlook towards lighting on the part of mine administrators.

Mr. W. H. DAVIS (*communicated*), commenting on the suggestion that mains lighting might possibly involve an addition to the risks of igniting firedamp, pointed out the advantages of air turbine lamps, which had been approved by the Mines Department for use anywhere underground. This type of lamp which, as the author had mentioned, had been used at Langwith and Norton collieries, compared quite well with mains equipment in regard to cost, and yet could be regarded as safe.

Mr. H. HOLT (*communicated*) remarked that much remained to be done, both below and above ground, in regard to efficient lighting. There was no difficulty, beyond initial expense, in the way of better surface illumination. Reports from collieries in the American anthracite field endorsed the good colour correction resulting from a combination of filament lamps and mercury discharge lamps.

Underground the position was more difficult. Daily changes in position of the light sources were necessary. At the face extra staff would be needed to prepare the circuit and remove it at the end of a shift. In many cases mains lighting had been tried out at one face only and the change-over effected by the existing staff. A universal application would mean a cutting down of productive charges but a considerable increase in maintenance and non-productive ones. No saving, or very little, would result from the reduction in hand lamps, and one must look to increase in output and decrease in compensation to balance depreciation, interest, and other overhead charges.

The author had included in the paper an interesting study of the economics at the Wenceslaus pit (Germany), but unfortunately April lamp figures were compared with December mains lighting figures. This, as regards demand, was all to the advantage of the latter system. Was information available that no other changes were made in the intervening six months on the mechanical side which would react in favour of the mains lighting output? One found so often that alterations in one direction suggested modifications in others in order that full advantage of the initial change might be taken.

In this country they had to meet a quota so that increased output per man shift would not offset overhead charges in the same way. It would certainly decrease production labour, but a smaller number of men would have to carry increased overheads. It would be interesting to know how many pits could, with safety, have 100 per cent. mains lighting installed and what percentage of the collieries in the United Kingdom had seams over 4 ft. in height.

Each case should be treated by the specialist on its merits, for it was dangerous to generalise where conditions were so variable. Better lighting was demanded, and must come in time, but it would, in the majority of cases, show a considerable increase in management charges, excluding compensation.

It had been stated that a decrease in nystagmus cases was likely if main lighting were universally installed. It was recorded that the disease was unknown in America, where cap lamps were used exclusively. This might be a reflection on the relative compensation laws, but in this country recognition

of the disease was quite recent and had developed with increase in lighting intensities below ground. Whether the introduction of higher candle-power lamps and better distribution would lead to a decrease in nystagmus could only be determined in practice.

In a paper before the American Illuminating Engineering Society (Trans. I.E.S. (U.S.A.), Vol. 29, No. 1, Jan., 1934) Mr. C. W. Owings, of the Bureau of Mines (U.S.A.), suggested as probable that about 35 per cent. of underground accidents are caused by inadequate and improper illumination. The paper also pointed out that the introduction of cap lamps had resulted in a 33.6 per cent. reduction in accidents in certain mines. What was more important, the accident severity rate (the number of days lost per 1,000 hours worked) was originally 43.7, as compared with 4.37 during the period after the change—practically a 90 per cent. decrease in severity.

Mr. J. W. Howell, replying to the discussion, agreed there would be some difficulty in using the high-pressure mercury lamp in mines in view of the regulations in this country, which require that the pressure in the system shall not exceed 125 volts. He did not agree that the flame lamp was more penetrating than the electric lamp, and, replying with regard to what Mr. Hailwood had said concerning the Nunnery Colliery experiment with mains lighting, he said he had not mentioned that because he did not think that experiment was sufficiently conclusive to put in the table. The use of cap lamps was spreading. Passing from a well-lighted part of the mine to one in which there was no illumination was, of course, the same as passing out of the beam of a motor-car headlight, but he had dealt with that in the part of the paper relating to adequate field brightness. As to statistics, it was necessary to have recourse to them from time to time, and he could only say that the statistics in the paper had been prepared with extreme care in eliminating outside elements. He did not agree with Mr. Long that he had taken extremes in dealing with the accident figures, and, taking the production figures as a whole, they did show a considerable improvement in output per man shift. Individually, perhaps, the increase might seem small, but, taken over a large number of men, the difference between 1.87 ton per man shift and 2.11 tons per man shift was a considerable improvement. With regard to sodium lighting, he had not yet come across it underground or on the screens, but he had heard of one case in which it was used on the screens, and then the mercury lamp finally displaced the sodium type. In conclusion, the author said he did not suggest that nystagmus would completely vanish with mains lighting, but indications were that it would be considerably reduced provided efficient lighting was installed.

At the conclusion of the discussion, thanks were expressed to the General Electric Co., Ltd., Messrs. Siemens Brothers. Ltd., Messrs. John Davis and Son, Ltd., and Messrs. Hailwood and Ackroyd for sending lamps for exhibit and demonstration.

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

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